2000 Survey for Blowout Penstemon (*Penstemon haydenii*) in Wyoming

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Abstract

Blowout penstemon, a federally Endangered plant, was probably first discovered in Wyoming by the Hayden survey in 1877, but remained unknown until 1996, when Frank Blomquist of the BLM Rawlins Field Office found a small population on public lands near Bradley Peak in the Seminoe Mountains of northwest Carbon County. Prior to 1996, this species was thought to be endemic to the Nebraska Sand Hills, nearly 300 km to the east. In 2000, a simple habitat model was used to identify high elevation sand dune areas across central and southern Wyoming for ground survey of *Penstemon haydenii*. Using this model, a new population was discovered on the slopes of Bear Mountain and Junk Hill at the eastern end of the Ferris Mountains. Blowout penstemon is now known from 15 extant locations in the Nebraska Sand Hills and the Ferris Mountain/Seminoe Mountain area of central Wyoming. Based on surveys in 2000, the total Wyoming population is estimated at 4150-5840 plants (compared to 3000-5000 individuals in Nebraska). As in Nebraska, Wyoming populations are restricted to shifting sand dunes and wind-carved, crater-like depressions (blowouts) with sparse cover of Blowout grass and Lemon scurfpea. The Wyoming sites, however, are located at higher elevations, and have lower mean annual precipitation and cooler summer temperatures. Wyoming populations also differ in being restricted to sand dunes associated with mountain slopes, rather than broad valleys. These mountain sites probably receive additional moisture from springs or enhanced surface runoff. Although legally protected under the Endangered Species Act, Blowout penstemon is still highly threatened by habitat loss (stemming from natural succession, fire suppression, or erosion-minimizing grazing rotation practices), impacts from ORV recreation, pesticides, over-collection, and insect predation. The US Fish and Wildlife Service has developed a recovery plan with the goal of protecting at least 15,000 individuals at 10 different sites. The discovery of new populations in Wyoming will help attain these de-listing objectives and could serve as a new source of genetic variability for reintroduction efforts.

Table of Contents

	Page
Abstract	2
Introduction	5
Methods	6
Species Information	6
Classification	6
Legal Status	6
Natural Heritage Rank	7
Description	7
Similar Species	8
Geographic Range	9
Extent of Surveys in Wyoming	9
Habitat	13
Population Size and Trends	16
Population Biology and Ecology	17
Current Management	19
Existing and Potential Threats	20
USFWS Recovery Plan	21
Summary	21
Acknowledgements	22
Literature Cited	23

Figures, Tables, and Appendices

Page

Figures

1. Line drawing of Blowout penstemon 7

2. Photo of Blowout penstemon in flower 8

3. Photo of Blowout penstemon in fruit and vegetative condition 9

4. Rangewide distribution of Blowout penstemon 10

5. Photo of Blowout penstemon habitat at Bear Mountain 12

6. Photo of Blowout penstemon habitat at Bradley Peak 13

7. Photo of Blowout penstemon habitat at Bradley Peak 14

8. Photo of Blowout penstemon habitat at Bear Mountain 15

9. Photo of Blowout penstemon habitat at Junk Hill 16

Tables

1. Locations of *Penstemon haydenii* in Wyoming 11

2. Species commonly associated with *Penstemon haydenii* in Wyoming 17

3. Demographic information for populations of *Penstemon haydenii* in Wyoming . . . 18

Appendices

A. Element Occurrence Records and Location Maps 25

B. Survey Routes 31

C. Potential Habitat Model of Blowout Penstemon 38

INTRODUCTION

Blowout penstemon (*Penstemon haydenii*) was first recognized as a distinct species by Sereno Watson (1891) based on a flowering specimen collected along the Dismal River in Thomas County, Nebraska in 1891 (Pennell 1920). At that time, the species was known from only one other record, a vegetative specimen collected by Ferdinand V. Hayden during "one of his early surveys" and originally identified as *Penstemon acuminatus* (a species now known to be endemic to the Columbia River Basin) (Watson 1891; Cronquist et al. 1984). Watson attributed the Hayden collection to "the Laramie Mountains of Wyoming", but Pennell (1935) later reported that a duplicate of Hayden's specimen at the Missouri Botanical Garden was labeled "Loup Fork", in the Nebraska Sand Hills. For the next 64 years, Blowout penstemon was presumed to be endemic to Nebraska (Stubbendieck et al. 1997).

Penstemon haydenii was considered locally abundant in the Nebraska Sandhills in the early 20th Century (Pool 1914), but by the 1940s was thought to be extinct (Fritz et al. 1992). Although the species was rediscovered in 1959, it remained extremely uncommon in west-central Nebraska and was listed as Endangered under the US Endangered Species Act in 1987. The species currently numbers between 3000-5000 plants at 13 sites in Nebraska (Stubbendieck et al. 1997).

In June 1996, Frank Blomquist of the Bureau of Land Management (BLM) Rawlins Field Office discovered a small population of Blowout penstemon on public lands at the west end of the Seminoe Mountains in northwestern Carbon County, Wyoming. The identity of this species was not confirmed until July 1999, when Blomquist and University of Wyoming botanists Amy Roderick, B. Ernie Nelson, Courtney Ladenburger, and Walter Fertig revisited the site and secured mature voucher material. These specimens were verified as *Penstemon haydenii* by Dr. Noel Holmgren of the New York Botanical Garden and Dr. James Stubbendieck of the University of Nebraska (Fertig 1999, 2000).

Blowout penstemon is currently Wyoming's only listed Endangered plant* and as of 1999 was still known only from the Seminoe Mountain area, approximately 300 km (185 miles) west of the nearest known population in Morrill County, Nebraska. In 2000, the BLM Wyoming State Office contracted with the University of Wyoming and the Wyoming Natural Diversity Database (WYNDD) to conduct a survey of potential Blowout penstemon habitat on public lands in central and southern Wyoming. The following report discusses the results of this survey and summarizes existing knowledge on the distribution, habitat, and abundance of this species in Wyoming.

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* Ute ladies tresses (*Spiranthes diluvialis*) and Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) are listed as Threatened and Desert yellowhead (*Yermo xanthocephalus*) is proposed for listing as Threatened.

METHODS

Information on the taxonomy, distribution, habitat, population size, and life history of Blowout penstemon was obtained from scientific literature, unpublished reports, specimens from the Rocky Mountain Herbarium (RM) and Chadron State College, and knowledgeable individuals. USGS topographic maps, geologic maps, air photos, and BLM land surface maps were used to identify areas of public land for ground survey. A simple habitat model (Appendix C) was also developed in GIS (Arc-view, version 3.1) to help select areas of potential habitat or surveys. Field surveys were conducted from 20 June-23 August 2000 (survey routes are shown in Appendix B). Data on habitat, phenology, population size, and associated species were collected using WYNDD plant survey forms. Populations were mapped on 7.5 minute USGS topographic maps and with a Global Positioning System (GPS). Information gathered in the field was entered into the computerized Element Occurrence database of WYNDD.

Permanent monitoring plots were not established due to the difficulty in placing permanent markers in deep, shifting sand and in setting up measuring tapes for transect grids under conditions of persistent strong winds. Alternative monitoring methodologies, such as permanent photo points or a complete population census, will be pursued in the future.

SPECIES INFORMATION

Classification:

Scientific Name: *Penstemon haydenii* S. Watson (1891). Watson originally spelled the specific epithet "*haydeni*", but a second "*i*" was later added to make the name etymologically correct (Fritz et al. 1992).

Common Name: Blowout penstemon; Hayden's penstemon, Blowout bluebells.

Family: Scrophulariaceae (Figwort family).

Synonyms: None.

Phylogenetic Relationships: The genus *Penstemon* contains nearly 250 species centered primarily in western North America (Cronquist et al. 1984). Blowout penstemon belongs to section *Coerulei*, a group recognized by succulent and glaucous leaves, anthers that dehisce their entire length, and compact inflorescences of blue, violet, pink, or white flowers (Cronquist et al. 1984). Blowout penstemon is unique within this section in having fragrant flowers (Freeman 1986). *P. haydenii* is thought to be most closely related to *P. grandiflorus* and *P. angustifolius*, and Freeman (1981) has hypothesized that *P. haydenii* may be of hybrid origin between these two taxa.

Legal Status: Blowout penstemon was listed as Endangered under the US Endangered Species Act on 1 October 1987 (Fritz et al. 1992). The plant is protected under state law in Nebraska, but receives no comparable protection in Wyoming.

Natural Heritage Rank: The Association for Biodiversity Information (formerly the heritage division of The Nature Conservancy) and the network of natural heritage programs gives *Penstemon haydenii* a rank of G1, indicating that the species is "critically imperiled because of extreme rarity" throughout its range. At the state level, it is ranked S1 in Nebraska and Wyoming (Nebraska Natural Heritage Program 1996; Fertig 2000).

Description: Blowout penstemon is a perennial herb with one to many glabrous stems arising from a branched caudex or rooting from buried nodes (Figures 1-3). Vegetative stems are usually less than 30 cm tall and have greenish-blue, waxy, linear leaves 2.5-12 cm long and 0.3-1 cm

Figure 1. Line drawing of Blowout penstemon by Bellamy Parks Jansen.

Figure 2. Photo of Blowout penstemon in flower on the steep sand dunes on the west side of Bradley Peak, Carbon County, WY, 2 July 1999. WYNDD photo by Walter Fertig.

wide. Flowering stems have narrow basal leaves and broad-based, clasping, waxy upper stem leaves 0.7-3 cm wide that taper abruptly to a narrow tip. The inflorescence is 6-16 cm long with 6-10 compact, leafy whorls of milky-blue to pale lavender flowers (rarely pink or white). Bracts of the inflorescence are broad and heart-shaped at the base and narrow to an elongate tip. Individual flowers are 23-25 mm long with tubular, bi-lobed and faintly vanilla-scented corollas and glabrous, linear sepals. Anther sacs are 1.8-2 mm long and glabrous. Fruits are 13-16 mm long capsules with light-brown, disc-shaped seeds with winged margins (Stubbendieck et al. 1982, 1997; Freeman 1986; Fertig 2000).

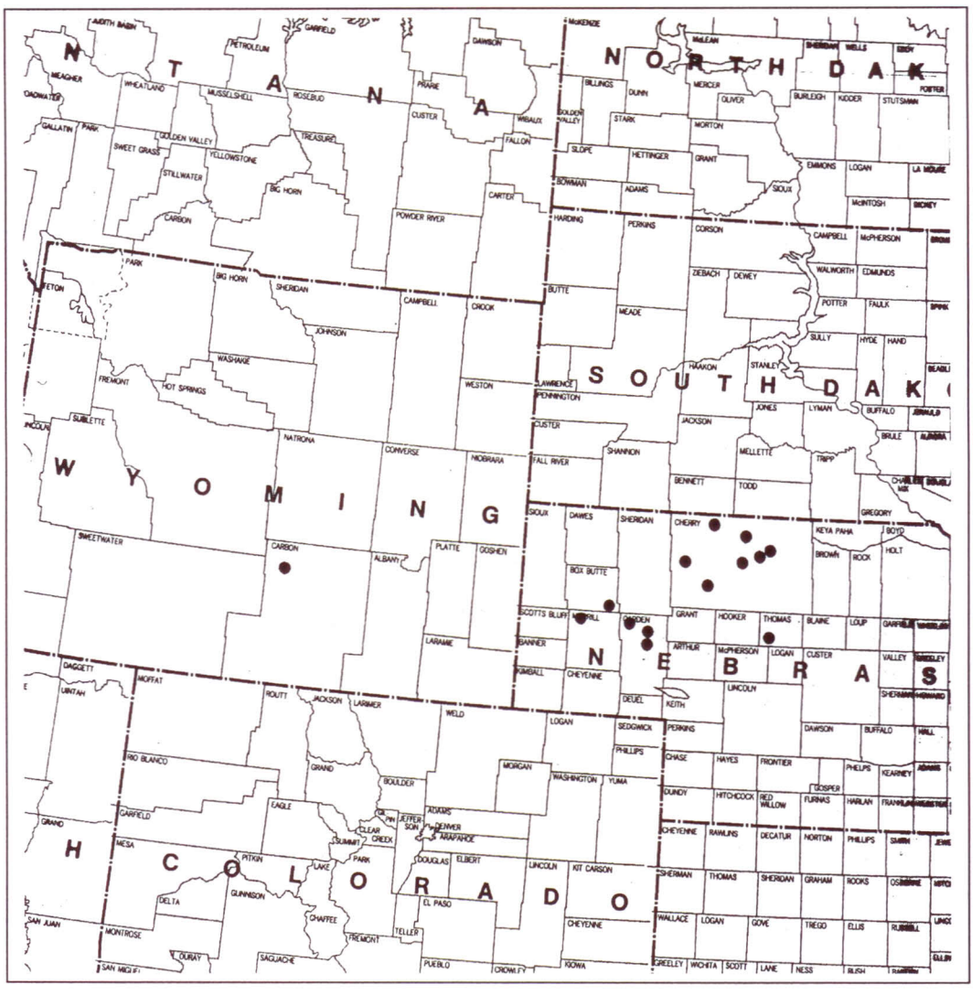
Similar Species: *Penstemon grandiflorus* has ovate to spoon-shaped leaves (widest above the middle), non-aromatic corollas over 35 mm long, and fruits over 16 mm long. *P. angustifolius* var. *angustifolius* has corollas less than 25 mm long and narrowly lance-shaped stem leaves over 7 times as long as wide (rarely over 1 cm wide). *P. angustifolius* var. *caudatus* has corollas under 25 mm long and lance-shaped to ovate flowering bracts (Freeman 1986; Dorn 1992).

Figure 3. Photo of Blowout penstemon in fruit (center) and vegetative condition (narrow, waxy-green leaves in foreground) from the dunes on the north side of Junk Hill, Carbon County, WY, 26 July 2000. WYNDD photo by Walter Fertig.

Geographic Range: Blowout penstemon is a regional endemic of the Sand Hills of west-central Nebraska (Box Butte, Cherry, Garden, Morrill, and Thomas counties) and the northeastern Great Divide Basin in Carbon County, Wyoming (Fig. 4) (Stubbendieck et al. 1997; Fertig 2000). Reports from Kansas (Coulter and Nelson 1909) are probably erroneous. Wyoming populations are found on the northwest flank of Bradley Peak in the western Seminoe Mountains and on the south slope of Bear Mountain and north side of Junk Hill at the eastern end of the Ferris Mountains, nearly 11.5 km (18.5 mi) east of US Highway 287 (Table 1; Appendix A). The Wyoming populations are subdivided into at least 8 main subpopulations that occupy about 80 acres within a 5 square mile area.

Extent of Surveys in Wyoming: The first record of Blowout penstemon in Wyoming comes from an undated collection made by the Hayden expedition and attributed to the "Laramie Mountains" by Watson (1891). Pennell (1920) noted that this specimen was possibly misidentified. Later, Pennell (1935) reported that a presumed duplicate of Hayden's specimen at the Missouri Botanical Garden was labeled "Loup Fork", a site in the Nebraska Sand Hills.

Figure 4. Rangewide Distribution of Blowout penstemon.



No other populations of Blowout penstemon were known outside of Nebraska until 1996, when Frank Blomquist of the BLM Rawlins Field Office discovered the plant on the west foothills of Bradley Peak in Carbon County (Fertig 2000). Uncertain about the identity of these plants, Blomquist and Amy Roderick of the University of Wyoming revisited the site in June 1998 to make a collection for verification. Although immature, this specimen was tentatively identified as *Penstemon haydenii* by Dr. Robert Dorn. On 2 July 1999, Blomquist, Roderick, and University of Wyoming botanists Walter Fertig, B. Ernie Nelson, and Courtney Ladenburger revisited the site and collected fresh flowering material. Field identification of *Penstemon haydenii* was subsequently confirmed by specimens sent to Dr. Noel Holmgren of the New York Botanical Garden and Dr. James Stubbendieck of the University of Nebraska (Fertig 2000).

Table 1.
Locations of *Penstemon haydenii* in Wyoming

Occurrence # 001
County: Carbon.
USGS Quad: Bradley Peak.
Latitude: 42° 10' 28" N (centrum)
South Latitude: 42° 10' 19" N
North Latitude: 42° 10' 32" N
Longitude: 107° 04' 45" W (centrum)
East Longitude: 107° 04' 32" W
West Longitude: 107° 04' 53" W
Town/Range/Section: T25N R86W S2 (NE4 OF SW4 OF NE4NE4); T26N R86W S35 (S1/2 OF SE4).
Location: West end Seminoe Mountains, sand dunes at head of School Creek on west side of Bradley Peak (ca 1.2 miles west of its summit), ca 4 miles south of Bear Mountain and ca 18.5 air miles east of US Highway 287.

Occurrence # 002
County: Carbon.
USGS Quad: Bradley Peak.
Latitude: 42° 13' 40" N (centrum)
South Latitude: 42° 13' 14" N
North Latitude: 42° 14' 31" N
Longitude: 107° 04' 40" W (centrum)
East Longitude: 107°0417W
West Longitude: 107°0506W
Town/Range/Section: T26N R86W S11 (NE4 OF SE4 OF SW4, NW4 OF SW4 OF SE4, SE4 OF NW4 OF SE4, E2 OF NW4 OF NE4 OF SE4, & S2 OF SE4SE4 OF NE4), S12 (NW4 OF SW4SW4 OF NW4, CENTER OF NW4 OF SW4 OF NW4, & NW4 OF NE4 OF SW4 OF NW4), S13 (W2 OF SE4 OF NW4 OF SW4), S14 (SE4 OF NE4NE4, SE4 OF NE4, N2 OF SE4 OF SW4 OF NE4; S2 OF NE4 OF SW4 OF NE4).
Location: East end of the Ferris Mountains, sand dunes on southeast slope of Bear Mountain, ca 2 air miles east of Sand Creek Canyon and 20 miles east-southeast of Muddy Gap and sand dunes on north side of Junk Hill, 1.25-2 miles west of Deweese Creek and 3.5-4 miles north of Bradley Peak.

In the summer of 2000, potential high-elevation sand dune habitat in the vicinity of the Ferris, Seminoe, and Green mountains and in the Killpecker Dunes and Sand Hills northeast of Baggs were targeted for ground survey (Appendix B, C). On 7 July, Blomquist and Fertig discovered an extensive population of Blowout penstemon on the south slopes of Bear Mountain at the eastern end of the Ferris Mountains. On a return trip on 26 July, Blomquist and Fertig located an additional colony on the north slope of adjacent Junk Hill and a large population on the sandy apron connecting the north side of Junk Hill and the south flank of Bear Mountain (Appendix A, occurrence # 002). No other populations were documented during 2000.

The discovery of the Bear Mountain population forces a reassessment of the disputed Ferdinand V. Hayden collection reported by Watson (1891) for Wyoming. Much of the confusion regarding Hayden's whereabouts stems from the assumption of Pennell (1920, 1935) that the *P. haydenii* collections from the Missouri Botanical Garden and Gray Herbarium are duplicates, when in fact, they probably represent different collections separated by 20 years and several hundred miles. Two

unnumbered (and probably duplicate) Hayden collections from the Missouri Botanical Garden are labeled "*Penstemon acuminatus* or *fendleri*" from the "Sand Hills, Loup Fork" by George Engelmann. These specimens were probably collected by Hayden during the 1856-1857 G.K. Warren expeditions through the Nebraska Sand Hills (Warren 1858). Hayden was responsible for the botany during this survey, with Engelmann providing identifications (Pound and Clements 1898). The Gray Herbarium specimen is labeled "*Penstemon acuminatus*" by Asa Gray, who was the botanist in charge of determinations for Hayden's 1877 expedition in Wyoming (Hayden 1879, p. *xx*). In August 1877, Hayden's party traveled from Casper to Rawlins through "Sandy Creek Pass" in the "Seminole Hills" (now called the Ferris Mountains). This route would have taken them through the low divide between the main massif of the Ferris Mountains and Bear Mountain (an unimproved county road goes through the pass today). In his *Eleventh Annual Report* of 1879, Hayden describes dunes near Sandy Creek Pass where "fine sand is blown up upon the hillsides for a distance of 500 to 600 feet" (Hayden 1879, p 138) and where "[l]ooking back upon the hills, the sand was found to reach up about 400 feet along their slopes" (Hayden 1879, p 32) (Figure 5). Since Hayden's party consisted largely of geologists, it is plausible that members of the group would have explored these dunes. According to Robert Dorn (2000), the specimen was probably collected by one of Hayden's assistants on 28 August and the location data for the specimen label

Figure 5. Blowout penstemon habitat on steep, south-facing sand dunes along the south side of Bear Mountain, east of "Sandy Creek Pass" , an area that may have been explored by the Hayden expedition in August 1877. WYNDD photograph by Walter Fertig, 26 July 2000.

("Laramie Mountains") could have easily been garbled (similar problems with incorrect labels have been noted on other Hayden collections). The phenology of the specimen (post fruiting) is consistent with a late season collection. Although it cannot be proven definitively, Hayden was clearly at the Loup Fork in 1857 and Sandy Creek Pass in 1877 and could have made separate herbarium collections at both sites, which were later incorrectly assumed to represent just the former locality. If Hayden did collect his namesake plant in Wyoming in 1877, allegations that this species was introduced to Wyoming from Nebraska become even less tenable (Fertig 2000).

Habitat: Blowout penstemon is restricted to sparsely vegetated, early successional, shifting sand dunes and blowout depressions created by wind erosion. In Wyoming, this species is found primarily on sandy aprons or the lower half of steep sandy slopes deposited at the base of granitic or sedimentary mountains or ridges (Figures 5-9). On unstable, windward slopes, Blowout penstemon may be found in communities of Blowout grass (*Redfieldia flexuosa*), Lemon scurf-pea (*Psoralidium lanceolatum*), and Thickspike wheatgrass (*Elymus lanceolatus* var. *lanceolatus*) with less than 5% vegetative cover (Table 2). Populations on more stable, lee slopes occur in similar communities with vegetative cover reaching 15-40%. Occasionally, populations may be found on

Figure 6. Habitat of Blowout penstemon on high sand dune on northwest flank of Bradley Peak (highest dune just to left of center of photo, below and to the left of the high point of Bradley Peak). *Penstemon haydenii* is absent from the lower elevation, rolling sand dunes in the middle foreground and from stabilized, sagebrush-dominated sand in the immediate foreground. WYNDD photo by Walter Fertig, 13 July 2000.

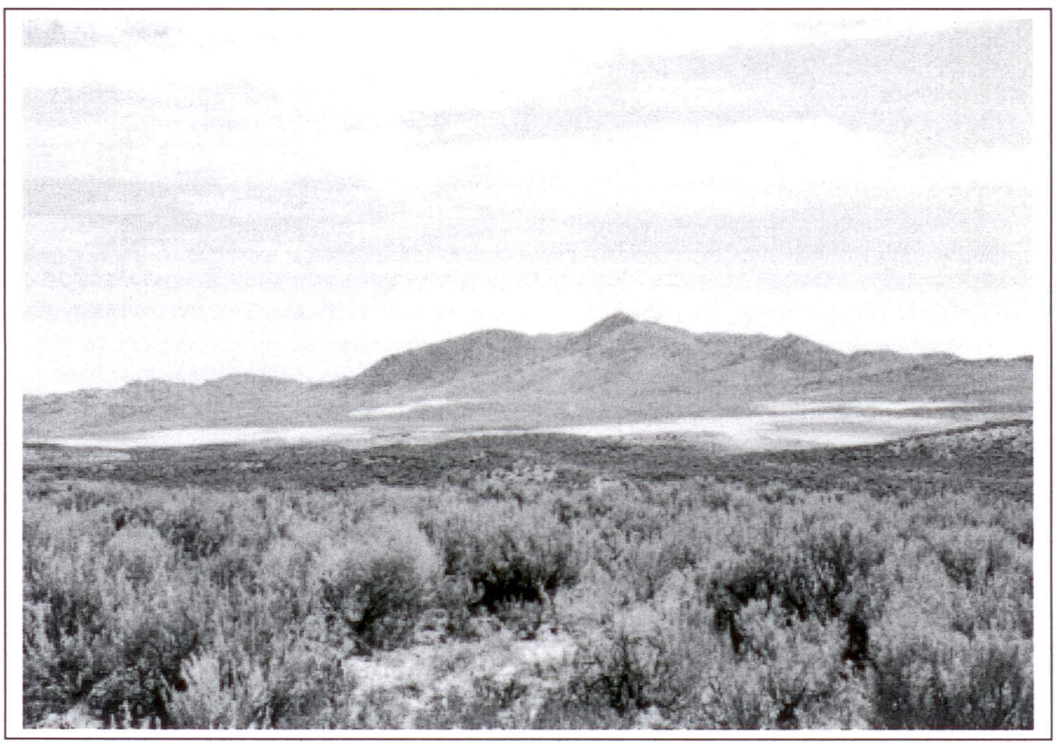


Figure 7. Habitat of Blowout penstemon on steep, north-facing sand dunes on the lee side of an active blowout on the southwest flank of Bradley Peak, 2 July 1999. Blowout penstemon is conspicuously absent from more stabilized slopes (at left center on photo). Less than 10% of the penstemon plants pictured above were present on this same slope on 6 July 2000. WYNDD photograph by Walter Fertig.

choppy dunes associated with Silver sagebrush (*Artemisia cana*) and Thickspike wheatgrass, or on barren slopes above small stands of Chokecherry (*Prunus virginiana*) and Stinging nettle (*Urtica dioica*) associated with seep springs.

The sand dunes in the Ferris and Seminoe Mountains consist of clay-rich psamments derived from wind-blown Quaternary alluvium (Love and Christiansen 1985). The dunes may be 18-36 m high (60-120 ft) and occur at elevations of 2035-2270 m (6680-7440 ft). Slopes range from about 25% on the north side of Junk Hill to nearly 60% on Bear Mountain and Bradley Peak. Average annual precipitation in the Ferris Dunes area is 254 mm (10 inches), with peak precipitation coming in April and May. Mean annual temperature is 6.6° C (44° F). Mean maximum and minimum temperatures in January are – 1.1 and -11° C (30 and 12° F) and mean maximum and minimum temperatures in July are 28.6 and 12.1° C (84 and 54° F) (Martner 1986).

The absence of *Penstemon haydenii* from the gently undulating dune fields found throughout the broad valley between the Ferris and Seminoe mountains may be related to the availability of soil moisture during the growing season. The primary source of moisture throughout the low sand dunes may be wind-blown snow and ice trapped in layers of insulating sand during the winter. Low spring and summer precipitation, coupled with high evapotranspiration rates and the natural porosity of the dunes, probably keeps the low elevation dunes too dry to support Blowout penstemon populations. Only those dunes perched high on mountain slopes may receive enough supplemental moisture from local springs or additional runoff to maintain this species. Elsewhere in Wyoming, Blowout penstemon is absent from sand-rich sites where vegetation cover is dense enough to reduce wind erosion and prevent the formation blowouts or shifting dunes.

Wyoming populations differ from those in the Nebraska Sandhills in occurring at higher elevations (2035-2270 m vs 853-1158 m), with lower mean annual precipitation (254 mm vs 425-625 mm), and cooler maximum and minimum summer temperatures. While vegetation structure and dominant species are similar between the two states, a large number of associated species found in Nebraska are not present at the Wyoming sites. These species include *Cycloloma atriplicifolia* (Ringwing), *Physalis heterophylla* (Clammy groundcherry), *Polanisia trachysperma* (Clammyweed), *Muhlenbergia cuspidata* (Plains muhly), *M. pungens* (Sandhill muhly), and *Eragrostis trichodes* (Sand lovegrass) (Fritz et al. 1992).

Figure 8. Habitat of Blowout penstemon on steep sand dune on south slope of Bear Mountain (view is looking west from a saddle between 2 parallel dunes. Blowout penstemon is restricted to the sparsely vegetated area at the top of the sand dune and on the adjacent slopes on the north and south sides (upper center of photo). Plants are absent from the active blowout at the bottom of the photo and the sagebrush-dominated stable sand fields to the right of the blowout. WYNDD photograph by Walter Fertig, 7 July 2000.

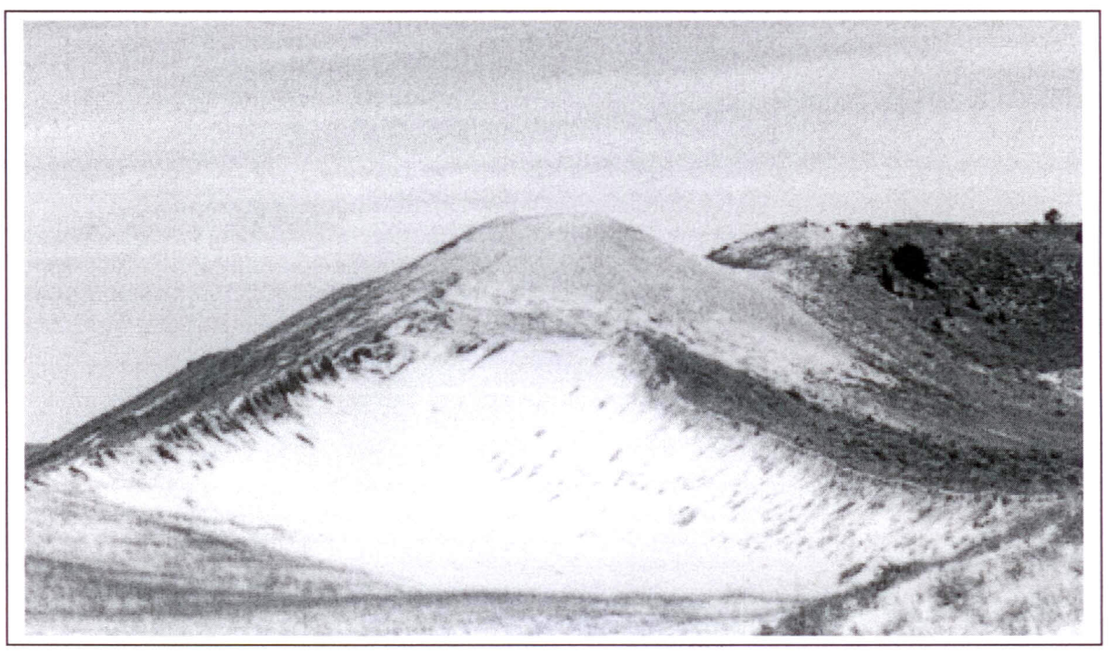


Figure 9, Habitat of Blowout penstemon on lower sandy slopes at north end of Junk Hill (WY Occurrence # 002). Plants occur on sparsely vegetated rolling dunes at center of photo and in choppy dunes in foreground dominated by *Artemisia cana* and *Psoralidium lanceolatum*. The sandy apron on the north side of Junk Hill connects with the dunes on the south side of Bear Mountain to form the largest known population of this species in Wyoming and probably the entire world. WYNDD photograph by Walter Fertig, 26 July 2000.

Population Size and Trends: Rangewide, Blowout penstemon is currently known from 13 extant locations in Nebraska (numbering 3,000-5,000 plants) and 2 in Wyoming. Based on surveys in 2000, the total Wyoming population is estimated at 4150-5840 individuals (Table 3; Appendix A). The largest population in the state (and apparently the world) occurs on the south slopes of Bear Mountain and adjacent Junk Hill, and numbered 3950-5540 plants in July 2000. The Bradley Peak population, estimated at 300-500 plants in 1999 (Fertig 2000), apparently declined to 200-300 individuals in 2000.

Long-term studies in Nebraska suggest that population size may fluctuate annually, depending on recruitment success and environmental stochasticity (Flessner and Stubbendieck 1992; Fritz et al. 1992). Historically, the Nebraska population has experienced a sharp decline. The exact reason for this decline is not known, although wildfire control, severe drought, improvements in range

Table 2. Species Commonly Associated with *Penstemon haydenii* in Wyoming

Scientific Name	Common Name	Growth Form
Arenaria nuttallii	Nuttall's sandwort	Perennial forb
Artemisia campestris var. *scouleriana*	Field sagewort	Perennial forb
Artemisia cana	Silver sagebrush	Shrub
Astragalus ceramicus var. *filifolius*	Painted milkvetch	Perennial forb
Calamovilfa longifolia	Prairie sandreed	Perennial graminoid
Chenopodium subglabrum	Smooth goosefoot	Annual forb
Cirsium canescens	Platte thistle	Perennial forb
Elymus lanceolatus var. *lanceolatus*	Thickspike wheatgrass	Perennial graminoid
Heterotheca villosa var. *hispida*	Hairy golden-aster	Perennial forb
Lesquerella ludoviciana	Louisiana bladderpod	Perennial forb
Lupinus sericeus	Silky lupine	Perennial forb
Lygodesmia juncea	Rush-like skeletonweed	Perennial forb
Machaeranthera canescens	Hoary aster	Perennial forb
Oenothera nuttallii	Nuttall's evening-primrose	Perennial forb
Oryzopsis hymenoides	Indian ricegrass	Perennial graminoid
Phacelia hastata	Silverleaf phacelia	Perennial forb
Psoralidium lanceolatum	Lemon scurf-pea	Perennial forb
Redfieldia flexuosa	Blowout grass	Perennial graminoid
Rumex venosus	Veiny dock	Perennial forb
Senecio spartioides var. *spartioides*	Broom groundsel	Perennial graminoid
Thermopsis rhombifolia	Round-leaved golden-pea	Perennial graminoid
Tradescantia occidentalis	Western spiderwort	Perennial forb

management (leading to reduced blowout production), leveling of sand dunes, and outbreaks of pyralid moths have all been identified as potential causes (Fritz et al. 1992).

Population Biology and Ecology: Blowout penstemon plants are not evenly distributed across their habitat, but are instead found in sparse, non-random clusters. In Nebraska, density typically varies from 1 plant per square meter to 1-2 plants over several hundred meters (Fritz et al. 1992). In unusually favorable microsites in Wyoming, density can be 2-3 plants per square meter (Table 3). Individual populations may range from 25 to over 2000 plants (Fritz et al. 1992).

Table 3.
Demographic Information for Populations of *Penstemon haydenii* in Wyoming

Occurrence # 001 (3 main subpopulations)	Occurrence # 002 (5 main subpopulations)
Area: 20 acres.	Area: 60 acres.
Number of Plants: Population estimated at 200-300 plants in July 2000.	Number of Plants: Total population estimated at 3950-5540 individuals in July 2000. Largest population estimated at 2000-3000 plants on the north side of Junk Hill. Bear Mountain population estimated at 1850-2420.
Density: Plants occur in widely scattered clumps. Density as high as 3-4 clumps per square meter in high quality habitat in 1999, but overall density and cover is trace.	Density: Occurs in widely scattered clumps, with individual clumps containing up to 3-5 plants per square meter. Total density and cover typically trace.
Evidence of Reproduction: 30% of population in fruit and 70% vegetative on 6 July 2000. 35% in flower and 65% vegetative on 2 July 1999.	Evidence of Reproduction: Less than 0.5% in flower on 7 July 2000. 10-30% in fruit.
Trends: Population seemed to be smaller in 2000 than in 1999, when 300-500 plants were observed (Fertig 2000).	Trends: Not known, although population may have been first documented in 1877 and is still extant.

Blowout penstemon flowers from May to early July in Nebraska and produces fruits from mid-June to mid-July. Occasionally, flowering may also occur from early August to early September (Fritz et al. 1992). Flowering in Wyoming occurs later than in Nebraska (late June to early July), probably in response to drier and cooler climatic conditions. In the drought year of 2000, flowering apparently peaked in late June and less than 0.5% of all plants were still in flower on 7 July. By contrast, flowering was at a peak on 3 July in 1999 (Fertig 2000).

Penstemon haydenii is pollinated mostly by four species of megachilid bees (*Hoplitis pilosifrons, Osmia distincta, O. cyaneonitens,* and *O. integra*), as well as wasps, ants, beetles, butterflies, and flies (Lawson et al. 1989). The plant is primarily an out-crosser, although experimental studies show that it is potentially self-fertile (Flessner and Stubbendieck 1992). Some inbreeding depression (lower mean number of fruit and seed and reduced mean seed weight) is evident in experimentally selfed plants (Flessner and Stubbendieck 1992).

Each fruit contains an average of 25-35 seeds and as many as 1500 seeds may be produced by each plant. Seeds are released from late August to September and either fall near the parent plant or are dispersed by wind or animals (Fritz et al. 1992; Stubbendieck et al. 1997). *Penstemon haydenii*

seeds have thick seed coats containing leachable chemical inhibitors. The seeds are often buried in shifting sand and can remain viable in the seedbank for 20 years (Stubbendieck et al. 1997). Prolonged wet conditions and abrasion are required for breaking dormancy and seed germination (Flessner 1988). Additional carryover mechanisms exist to regulate water uptake and germination of seeds, thus preventing the entire seed pool from germinating at once under seemingly favorable conditions (Caha et al. 1998). Despite potential inbreeding due to limited pollen exchange between isolated populations, *P. haydenii* seeds have a 90% germination rate under experimental conditions following seed coat scarification (Stubbendieck et al. 1982; Flessner 1988). Under natural conditions, seedling production is exceedingly low due to high levels of insect and rodent predation, plant pathogens, and unfavorable climatic conditions (Caha et al. 1998). Good seedling establishment may only occur every 8-10 years (Stubbendieck et al. 1997).

Blowout penstemon is also capable of spreading vegetatively by the production of adventitious roots from buried stems (Barr 1982; Stubbendieck et al. 1997). This is an adaptation for surviving constant burial by wind-blown sand, a feature shared by many other plants in its sand dune habitat.

Caha et al. (1998) studied genetic variability in mitochondrial and chloroplast DNA from a subset of Nebraska populations of *Penstemon haydenii*. Although no difference could be detected in chloroplast DNA, at least 8 distinct markers were found in mitochondrial DNA, indicating a greater amount of genetic variability than would be expected in an inbreeding population. This variability could be due to high levels of gene flow between populations in the past. Such gene flow is no longer possible in today's fragmented landscapes. Intrapopulational genetic diversity may also be enhanced by the long-lived seed bank of this species, which allows new cohorts of seedlings to contain a mix of ages and genealogies (Caha et al. 1998). The genetic structure of the Bradley Peak population is currently being investigated by Dr. Allen Szalanski of the University of Nebraska using leaf tip samples collected by Frank Blomquist in 1999. Preliminary results in early 2000 found little divergence between this population and others sampled in Nebraska (Gerry Steinauer, personal communication).

Current Management: Wyoming populations of Blowout penstemon occur on lands managed by the State of Wyoming and the BLM Rawlins Field Office. Under the Great Divide Resource Management Plan (USDI Bureau of Land Management 1990), the BLM lands are managed for livestock grazing, mineral development, and recreation. The entire area is open to oil and gas leasing, locatable minerals, and geophysical exploration. Off-road vehicle travel is limited to existing roads and trails, but without any seasonal use restrictions. Both dunes sites are managed for full fire suppression.

In Nebraska, *Penstemon haydenii* is protected at two sites in the Valentine Lake and Crescent Lake National Wildlife Refuges. Protected populations also occur at Ballard's Marsh Wildlife Management Area (managed by the Nebraska Game and Parks Commission) and The Nature Conservancy's Graves Ranch preserve (Gerry Steinauer, personal communication). All other known populations are on private or state lands managed primarily for agriculture (Fritz et al. 1992).

Existing and Potential Threats: The following threats have been identified for this species in the literature (Fritz et al. 1992):

Changes in Habitat Quality: Historically, fire and grazing by bison and livestock helped maintain the blowout habitat of *Penstemon haydenii* by removing sand-stabilizing vegetation. The implementation of fire-control policies in the 1870s following white settlement, elimination of bison, initiation of soil conservation programs, and increased usage of rotational grazing systems have reduced the incidence of wind erosion, resulting in the loss of Blowout penstemon habitat and a reduction in its population size in Nebraska (Fritz et al. 1992). Threats from habitat change appear low in Wyoming under current grazing practices and stocking rates and due to the remoteness of the area.

Livestock Trampling and Grazing: Blowout penstemon is edible to cattle and horses, but is not preferred forage if other vegetation is available. During non-drought conditions, grazing on *P. haydenii* is minor and confined mostly to occasional shoots. Such grazing can be stimulatory in breaking apical dominance (Fritz et al. 1992). When other forage is severely limited, as during drought conditions, severe grazing damage can occur (the entire above-ground portion of the plants may be eaten). Due to the sparse distribution of this plant and its shifting substrate, trampling damage is rarely significant (Fritz et al. 1992). Stem damage from grazing was observed on nearly 10% of the population at Bear Mountain and Junk Hill in 2000 and on 60-80% of stems at Bradley Peak in July 2000. Much of this herbivory may be due to elk or mule deer based on the abundance of their tracks, rather than domestic stock, which seem to prefer the adjacent wet, grassy meadows to the barren dunes.

Over-collection: Many rare penstemon species are vulnerable to over-collection for seed or garden stock. Small populations near state highways are considered especially vulnerable to this threat in Nebraska. Specific site locations have been kept confidential to reduce the threats from overharvest (Fritz et al. 1992). The Wyoming populations are probably sufficiently isolated and inaccessible to protect them from over-collection at the present time.

Off-road Vehicles: The sand dune habitats of Blowout penstemon are often popular for off-road vehicle (ORV) recreation, especially on state and public lands where access is not as stringently regulated as on private lands. Hill-climbing and other ORV activities can accelerate natural erosion, but driving over the plants leads to high mortality (Fritz et al. 1992). The Wyoming populations are sufficiently remote at present to offer some protection from high ORV use. BLM recreation planners should be made aware of the possible impacts to these populations from ORV use.

Pesticides: The direct impact of herbicides on Blowout penstemon is not known, although the plant is probably vulnerable to broadleaf weed killers (Fritz et al. 1992). Due to the sparse cover of its habitat, herbicide application rates are minimal in Nebraska and Wyoming at present. The use of insecticides to combat range pests (such as grasshoppers) is a potential threat to the pollinators of this species.

Construction Activities: Construction of permanent roads within the occupied habitat of *Penstemon haydenii* is unlikely to be a threat due to the unsuitability of shifting sand as a road surface. Powerlines and pipeline construction could have short-term impacts if plants are uprooted during the building phase. Home construction is unlikely given the unstable substrate.

Natural Threats: Natural succession, in which formerly shifting dunes and blowouts become stabilized with a cover of prairie grasses, is a potential threat to existing populations of Blowout penstemon. Extensive drought, such as the Dust Bowl drought of the 1930s, has been suspected as a cause of the serious decline of this species in the early 20th century. While drought could create new habitat by killing grass cover and making sites more prone to erosion, *Penstemon haydenii* may itself be vulnerable to prolonged water stress. Insect outbreaks may also pose a threat. *P. haydenii* is preyed upon by spider mites, grasshoppers, penstemon aphids, and *Endothenia hebesana* (a seed predator) (Fritz et al. 1992). The most serious pest is probably the larvae of pyralid moths, which bore into the stems and rootcrowns of Blowout penstemon to pupate and can cause 75% mortality (Stubbendieck et al. 1997). Fungal root rots can also cause death through wilting (Fritz et al. 1992).

USFWS Recovery Plan: The US Fish and Wildlife Service commissioned a recovery plan for Blowout penstemon in the early 1990s and has been funding basic research into the life history and management needs of this species in Nebraska for nearly two decades (Fritz et al. 1992). The primary objective of the recovery plan is to reach a stable, rangewide population threshold of at least 15,000 individuals in 10 population groups (each with a minimum of 300 plants at the lowest ebb of a population cycle). To reach this goal, new populations may need to be reintroduced into the historic range of the plant. A minimum level of protection is also needed for each of the target populations (Fritz et al. 1992).

The discovery of new Blowout penstemon populations in Wyoming (well outside its' presumed historic range) is extremely significant for the protection and future de-listing of this species (Fertig 2000). If genetically unique, the Wyoming population will provide an important source of seed and pollen for gene banking and possible introduction to new sites. The discovery also raises the possibility that the species may be more widespread (and thus less imperiled) than traditionally thought. Surveys in sand dune habitats outside of the Nebraska Sandhills (including eastern, central, and southwest Wyoming, northeast Colorado, and possibly southern South Dakota) may now be warranted. Protection of the Wyoming occurrences will also help achieve the de-listing goal of 10 populations with a minimum of 300 individuals.

SUMMARY

Blowout penstemon, a federally Endangered plant, was probably first discovered in Wyoming by the Hayden survey in 1877, but remained unknown until 1996, when Frank Blomquist of the BLM Rawlins Field Office found a small population on public lands in the Seminoe Mountains of northwest Carbon County. Prior to 1996, this species was thought to be endemic to the Nebraska Sand Hills, nearly 300 km to the east. In 2000, the Seminoe Mountain population was revisited and a new population was discovered approximately 5 miles to the north on the slopes of Bear

Mountain and Junk Hill at the east end of the Ferris Mountains. Blowout penstemon is now known from 15 extant locations in the Nebraska Sand Hills and the Ferris Mountain/Seminoe Mountain area of central Wyoming. Based on surveys in 2000, the total Wyoming population is estimated at 4150-5840 plants (compared to 3000-5000 individuals in Nebraska). As in Nebraska, Wyoming populations are restricted to shifting sand dunes and wind-carved, crater-like depressions (blowouts) with sparse cover of Blowout grass and Lemon scurfpea. The Wyoming sites, however, are located at higher elevations than in Nebraska, and have lower mean annual precipitation and cooler summer temperatures. As a result, populations in Wyoming produce flowers and fruits at a later date than in Nebraska. Wyoming populations also differ in being limited to dunes found high on mountain slopes, rather than broad valleys. These mountain sites probably receive additional moisture from springs or enhanced runoff. Although legally protected under the Endangered Species Act, Blowout penstemon is still highly threatened by habitat loss (stemming from natural succession, fire suppression, or erosion-minimizing grazing rotation practices), impacts from ORV recreation, pesticides, over-collection, and insect predation. The US Fish and Wildlife Service has developed a recovery plan with the goal of protecting at least 15,000 individuals at 10 different sites. The discovery of new populations in Wyoming will help attain these de-listing objectives and could serve as a new source of genetic variability for reintroduction efforts.

ACKNOWLEDGEMENTS

I would like to thank the following individuals for their assistance with this project: Frank Blomquist, of the BLM Rawlins Field Office shared his knowledge of the Bradley Peak population, led several expeditions to the site, helped identify additional potential survey sites in central Wyoming, provided GPS maps of location sites, and accompanied me on two trips to the Ferris Mountains that resulted in the discovery of new populations of Blowout penstemon; Dr. Robert Dorn tracked down historical information from the Hayden expedition of 1877 and provided a photocopy of Hayden's Wyoming collection from the Gray Herbarium; Dr. Noel Holmgren of the New York Botanical Garden corroborated our identification of a voucher specimen of *Penstemon haydenii* from Bradley Peak; Dr. James Stubbendieck of the University of Nebraska also confirmed the identity of our specimens and shared his knowledge of this species in Nebraska; Dr. Ronald Weedon of Chadron State College kindly shared his expertise and provided numerous reprints; Amy Roderick, Laura Welp, Courtney Ladenburger, B. Ernie Nelson, Jim Glennon, Mike Evans, Charmaine Delmatier, and Jeff Carroll assisted with field surveys in 1999-2000; Gerry Steinauer of the Nebraska Natural Heritage Program provided information on populations in Nebraska; Dr. Allen Szalanski of the University of Nebraska shared preliminary data from his genetic analyses of Wyoming populations (final results are still in preparation); Dr. James Solomon of the Missouri Botanical Garden provided photocopies of *P haydenii* specimens collected by Hayden in 1857; Doug Whisenhunt of The Nature Conservancy Nebraska State Office shared monitoring information from TNC's Graves Ranch preserve; and Jeff Carroll of the BLM Wyoming State Field Office provided funding and logistic support.

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Appendix A.

Element Occurrence Records and Location Maps

WYOMING NATURAL DIVERSITY DATABASE
-Element Occurrence Record-

PENSTEMON HAYDENII
BLOWOUT PENSTEMON
Occurrence # 001

Status
Data Sensitive?: No
Identification verified: Yes
Global Rank: G1
WYNDD State Rank: S1
Federal Status: Listed Endangered
WY Distribution Note: Regional Endemic

Location
County: Carbon
USGS Quad Name: Bradley Peak
Latitude: 421028N (centrum)
South Latitude: 421019N
North Latitude: 421032N
Longitude: 1070445W (centrum)
East Longitude: 1070432W
West Longitude: 1070453W
Map Accuracy: Precise; location is within a 75 foot radius of point on USGS topo map.
Town/Range/Section: T25N R86W S2 (NE4 OF SW4 OF NE4NE4); T26N R86W S35 (S1/2 OF SE4).
Location: West end Seminoe Mountains, sand dunes at head of School Creek on west side of Bradley Peak (ca 1.2 miles west of its summit), ca 4 miles south of Bear Mountain and ca 18.5 air miles east of US Highway 287.

Population Data
Last Observed: 2000-07-06
First Observed: 1996-06
Data: Occurrence consists if 3 main subpopulations in an area of 0.25 x 0.25 square miles.

2000-07-06: Site resurveyed by W. Fertig, Frank Blomquist, Jeff Carroll, Robert Dorn, Laura Welp, Jim Glennon, Mike Evans, and Charmaine Delmatier. Population smaller than in 1999, with many clumps missing (some possibly buried by sand). Population estimated at 200-300 individuals, ca 30% in fruit and 70% vegetative (only 1 flowering plant observed). Herbivory very high, with an estimated 60-80% of fruiting stems showing signs of being browsed (probably by antelope, deer, or elk). Occurs with *Lygodesmia juncea, Heterotheca, Senecio spartioides* var. *spartioides, Chenopodium subglabrum, Cirsium canescens*, and *Machaeranthera canescens.*

1999-07-22: Plants observed in fruit by Frank Blomquist and Jim Stubbendieck.

1999-07-02: Population estimated at 300-500 clumps in survey by W. Fertig, Amy Roderick, Frank Blomquist, Ernie Nelson, and Courtney Ladenburger. Approximately 35% of the population in flower and 65% vegetative. Flowers are milky-lavender in color and have a distinctive vanilla-like smell. Vegetative plants have more slender leaves. Plants often with many stems from a perennial rootstalk (1-30 stems) and are mostly clumped. Average density of 3-4 clumps per square meter observed in

occupied habitat. Population divided into 3 main groups, the largest with 164 plants (94 vegetative/70 flowering). Individual plants or smaller clusters found between the main subpopulations or at the periphery of the area.

1998-06-15: Observed in bud by Amy Roderick and Frank Blomquist.

1996-06: Population initially discovered and photographed by Frank Blomquist.

Habitat: Occurs in 2 main habitats: (1) Steep, NW-facing slopes of active sand dune with less than 5% cover of *Redfieldia flexuosa, Elymus lanceolatus, Psoralidium lanceolatum*, and occasional *Chrysothamnus nauseosus*; (2) North facing sandy slopes (slope ca 30%) on lee side of active blowout with 25-40% cover of *Psoralidium lanceolatum/Oryzopsis hymenoides/Elymus smithii* vegetation.
Elevation: 7200-7440 feet
Size: 20 acres

Comments: First report of this species for Wyoming (formerly considered endemic to the Nebraska Sand Hills).

Managed Area: BLM Rawlins Field Office.

Management Comments: Area is part of a livestock grazing allotment. Grazing use appears minimal due to low amount of forage and lack of water. Site was being considered for a sand quarry in the past, but sand was too high in fine clay content to be economically useful. Area is not used for ORV recreation at present.

Specimens:
Roderick, A., F. Blomquist, B.E. Nelson, W. Fertig, & C. Ladenburger (8527). 1999. RM, NE, NY.
Roderick, A. (5013). 1998. NY, RM.

Sources:
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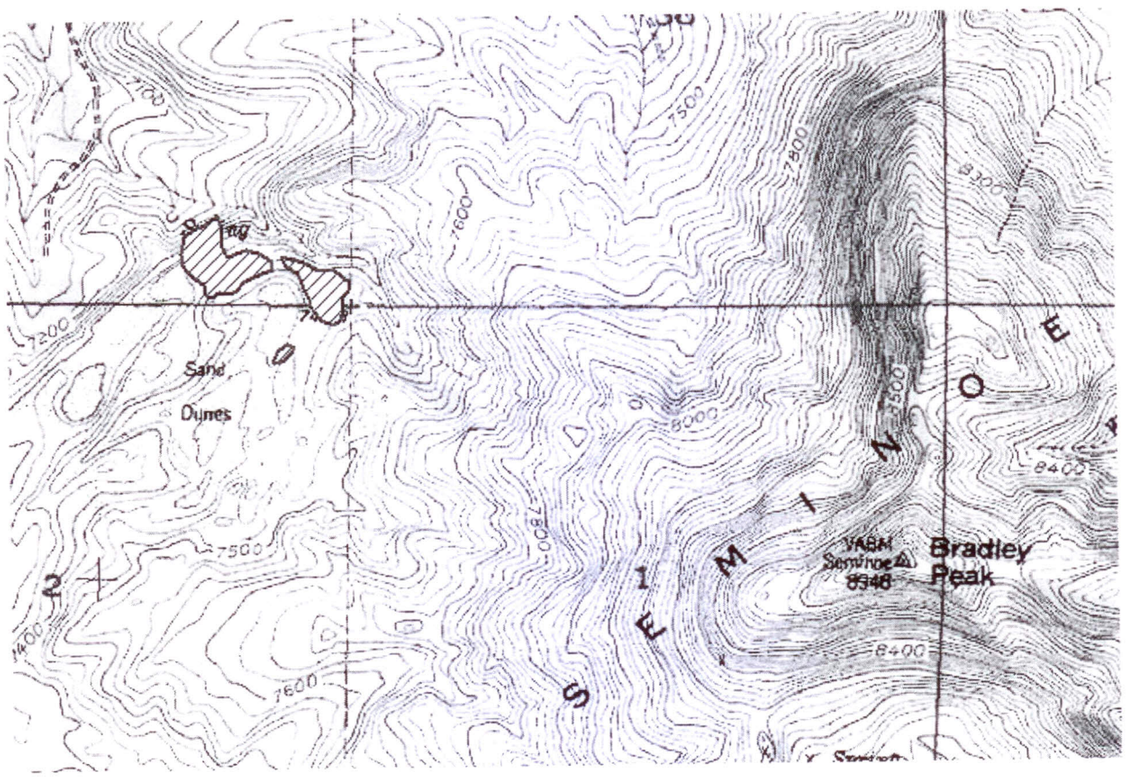
Author: Walter Fertig
Edition Date: 00-07-18

Penstemon haydenii Occurrence # 001
Bradley Peak Quad

T25N R86W S2 & T26N R86W S35
Sandy slopes on west flank of Bradley Peak



WYOMING NATURAL DIVERSITY DATABASE
-Element Occurrence Record-

PENSTEMON HAYDENII
BLOWOUT PENSTEMON
Occurrence # 002

Status
Data Sensitive?: No
Identification verified: Yes
Global Rank: G1
WYNDD State Rank: S1
Federal Status: Listed Endangered
WY Distribution Note: Regional Endemic

Location
County: Carbon
USGS Quad Name: Bradley Peak
Latitude: 421340N (centrum)
South Latitude: 421314N
North Latitude: 421431N
Longitude: 1070440W (centrum)
East Longitude: 1070417W
West Longitude: 1070506W
Map Accuracy: Precise; location is within a 75 foot radius of point on USGS topo map.
Town/Range/Section: T26N R86W S11 (NE4 OF SE4 OF SW4, NW4 OF SW4 OF SE4, SE4 OF NW4 OF SE4, E2 OF NW4 OF NE4 OF SE4, & S2 OF SE4SE4 OF NE4), S12 (NW4 OF SW4SW4 OF NW4, CENTER OF NW4 OF SW4 OF NW4, & NW4 OF NE4 OF SW4 OF NW4), S13 (W2 OF SE4 OF NW4 OF SW4), S14 (SE4 OF NE4NE4, SE4 OF NE4, N2 OF SE4 OF SW4 OF NE4; S2 OF NE4 OF SW4 OF NE4).
Location: East end of the Ferris Mountains, sand dunes on southeast slope of Bear Mountain, ca 2 air miles east of Sand Creek Canyon and 20 miles east-southeast of Muddy Gap and sand dunes on north side of Junk Hill, 1.25-2 miles west of Deweese Creek and 3.5-4 miles north of Bradley Peak.

Population Data
Last Observed: 2000-07-26
First Observed: 1877-08-28
Data: Occurrence consists of 5 subpopulations in an area of 1 x 1.5 miles. Total population in 2000 estimated at 3950-5540 plants.

2000-07-26: Sec 14 NE4 subpopulation (valley between Junk Hill and Bear Mountain): Extensive population of 2000-3000 observed by W. Fertig and Frank Blomquist. Density averages 3-5 plants per square meter on open slopes. Ca 30% in fruit and 70% vegetative. Occurs with *Psoralidium lanceolatum, Redfieldia flexuosa, Elymus smithii, Lygodesmia juncea, Oryzopsis hymenoides*, and *Chenopodium subglabrum*. About 15% of population shows evidence of being browsed. Plants most abundant on crest of dune in *Redfieldia* community and in smaller dunelets dominated by *Artemisia cana*. Sparse to absent from more densely vegetated slopes with cover greater than 30%. Sec 13 SW4 subpopulation (north side Junk Hill): 80 plants observed by Fertig and Blomquist in walk-through survey, population estimated at 100-120. Occurs with *Chrysothamnus nauseosus, Oenothera, Rumex venosus, Cirsium canescens, Artemisia tridentata, Redfieldia flexuosa*, and *Heterotheca*. Plants typically occur in small clusters of 3-5 and occur sporadically on E and N slopes (absent from active blowout). Only 10% in fruit and less than 2% are seedlings. Fruits aborted in 5 of 7 plants. Ca 10% of plants show damage from herbivory.

2000-07-07: Sec 11 NW4SE4 subpopulation (S slope Bear Mountain): 191 plants observed by Fertig and Blomquist, with the population

estimated at 300-570. Ca 70% of the population vegetative and 30% in fruit. No seedlings observed. Plants occur in scattered clusters of 1-4 individuals. Occurs with *Astragalus ceramicus, Lupinus sericeus, Leucopoa kingii, Phacelia hastata, Thermopsis, Arenaria nuttallii, Lygodesmia juncea, Rumex venosus, Cirsium canescens, Artemisia campestris, Comandra umbellata, Artemisia cana*, and *Tradescantia occidentalis*. Sec 11 NE4SE4 colony: Small population of 50 plants observed at edge of blowout overlapping granite knob. Plants all in fruit or vegetative. Sec 11 SE4NE4/Sec 12 NW4 colony: 951 plants observed in 2 main concentrations (largest, with 918 plants, is along the dune field in Sec 12). Population estimated at 1500-1800 plants. Ca 65% vegetative and 35% in fruit (only 1 plant observed still in flower). Density as high as 3-4 plants per square meter. Ca 10% of plants show some evidence of herbivory.

1877-08-28: Type specimen probably collected here by an assistant to Ferdinand Hayden. Plants in late fruit.

Habitat: Occurs in 5 main habitats: (1) rims or midslopes of steep (50-60%), north-facing slopes on lee side of active sand dunes in community of *Psoralidium lanceolatum/ Elymus lanceolatus*. Vegetative cover 5-15%. (2) Steep (60%) south-facing sand slope on lee side of blowout in community of *Psoralidium lanceolatum/Elymus lanceolatus* with 20-30% vegetative cover above seep springs dominated by dense (but heavily browsed) thicket of *Prunus virginiana* and *Urtica dioica*. (3) Base of steep (50-60%), barren sand dune with no other vegetative cover. (4) Among small, choppy dunes dominated by *Artemisia cana* and *Elymus lanceolatus*. (5) *Redfieldia flexuosa* community on sandy apron at base of rocky mesa.
Elevation: 6680-7040 feet
Size: 60 acres

Comments: Largest known population in Wyoming, and possibly the largest in the world.

Managed Area: BLM Rawlins Field Office and State of Wyoming

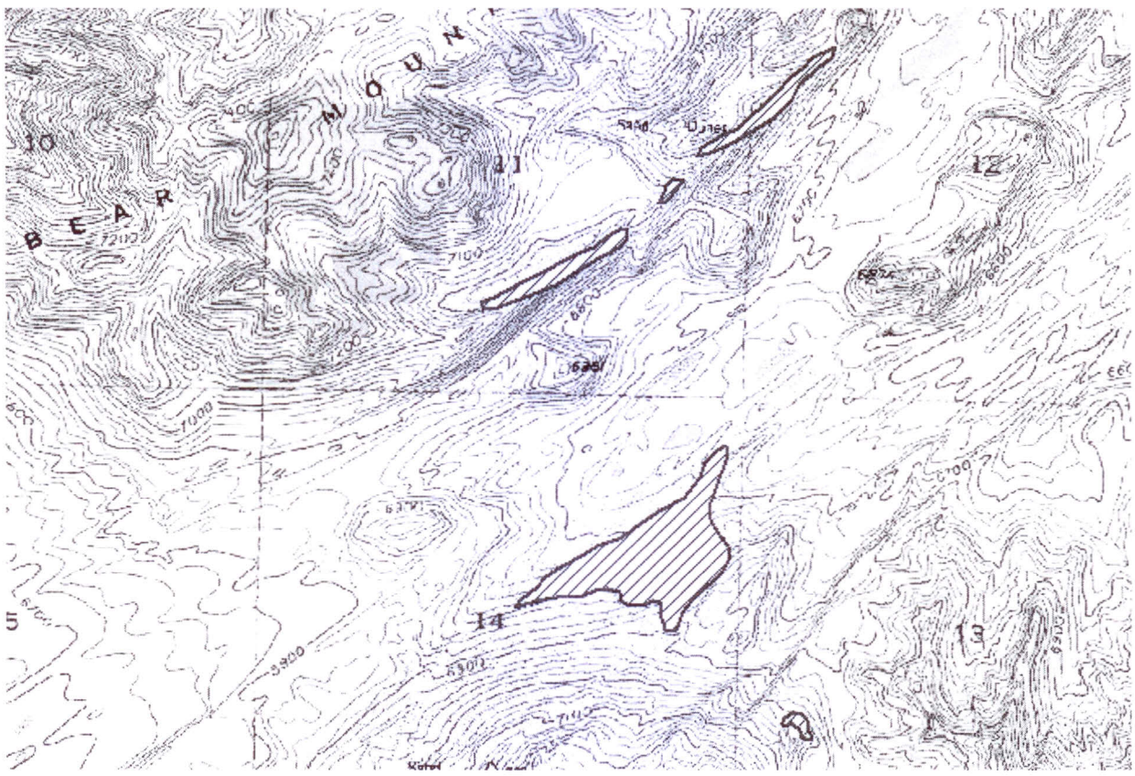
Management Comments: Site is managed for cattle grazing and recreation. Livestock use is concentrated in the valley between Junk Hill and Bear Mountain (especially in the vicinity of several ponds) and appears to be low in the surrounding dunes (little evidence of dung or tracks). Site also supports large herd of pronghorn, mule deer, and probably elk in the winter. Up to 15% of stems have been browsed.

Specimens: Hayden (s.n.). 1877. G.

Author: Walter Fertig
Edition Date: 01-02-13

Penstemon haydenii Occurrence # 002
Bradley Peak Quad

T26N R86W S11-14
Sandy ridge on south side of Bear Mountain and sandy slopes and apron on north side of Junk Hill



Appendix B.

Survey Routes

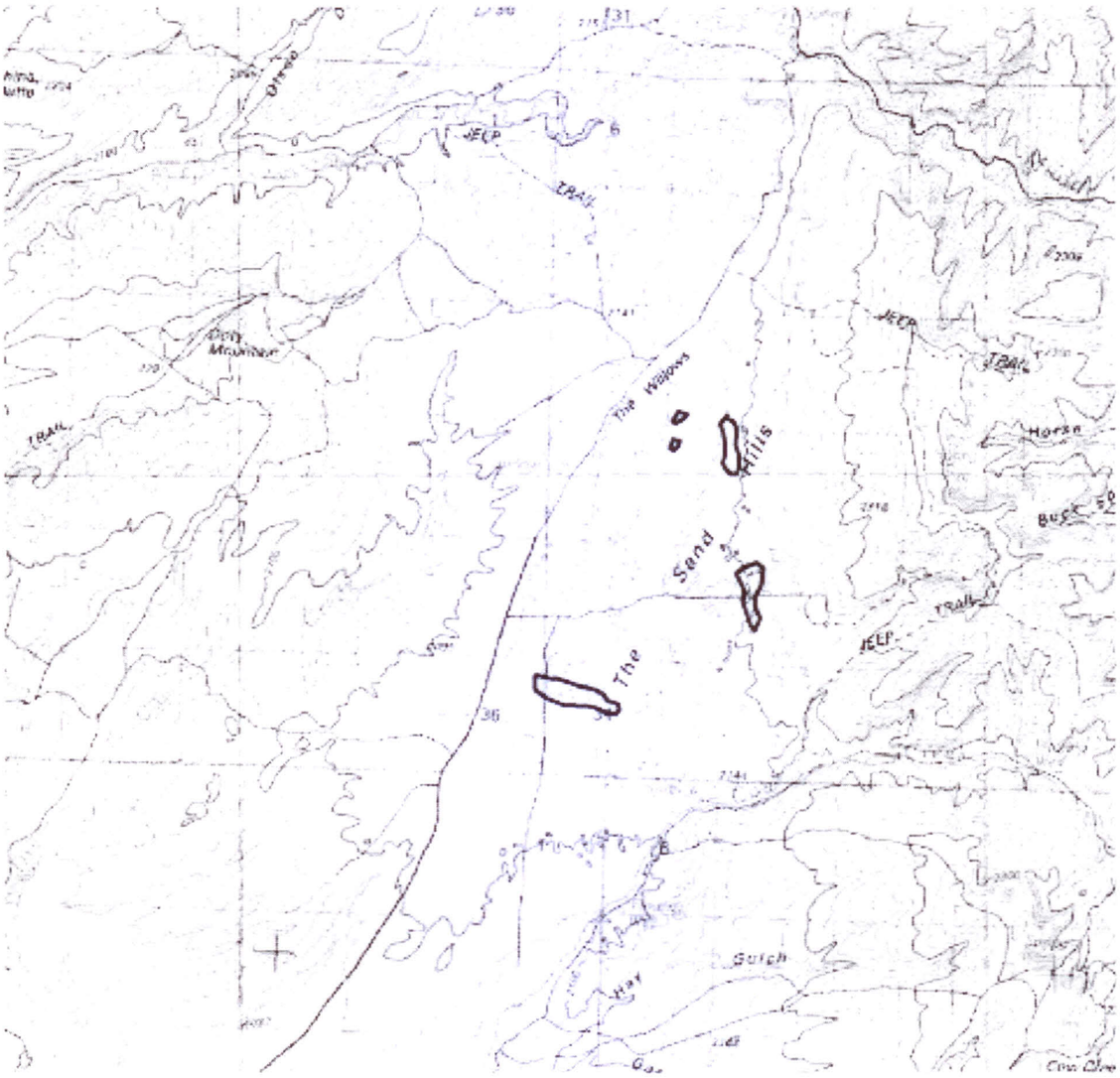
Surveys for Blowout penstemon were conducted by Walter Fertig and Frank Blomquist from June-August 2000. Potential areas for survey were determined from BLM land management maps, USGS topographic maps, geologic maps, and locations selected from a model of potential habitat (Appendix C). Surveyed locations are depicted on the accompanying maps and are summarized below:

Surveyed Sites 2000
(see the following maps for exact locations)

DATE	SURVEYOR	COORDINATES	BLOWOUT PENSTEMON FOUND?
20 June 2000	Fertig	T17N R90W S20	No
20 June 2000	Fertig	T17N R90W S29	No
20 June 2000	Fertig	T17N R90W S31	No
6 July 2000	Fertig, Blomquist, Dorn, Welp, Carroll, Glennon, Evans, & Delmatier	T26N R86W S35	Yes (EO # 001)
6 July 2000	Fertig, Blomquist, Dorn, Welp, Carroll, Glennon, Evans, & Delmatier	T25N R86W S3	No
7 July 2000	Fertig & Blomquist	T26N R86W S11-12	Yes (EO # 002)
12 July 2000	Fertig	T25N R86W S31	No
12 July 2000	Fertig	T25N R86W S32	No
12 July 2000	Fertig	T24N R86W S3	No
13 July 2000	Fertig	T25N R87W S1	No
13 July 2000	Fertig	T26N R87W S27	No
13 July 2000	Fertig	T27N R91W S30	No
13 July 2000	Fertig	T27N R92W S14	No
15 July 2000	Fertig	T23N R104W S6	No
15 July 2000	Fertig	T24N R104W S33	No
16 July 2000	Fertig	T23N R102W S18	No
16 July 2000	Fertig	T23N R103W S16-17	No
26 July 2000	Fertig & Blomquist	T26N R86W S13	Yes (EO # 002)
26 July 2000	Fertig & Blomquist	T26N R86W S14	Yes (EO # 002)
23 August 2000	Fertig	T25N R84W S32	No
23 August 2000	Fertig	T25N R85W S25	No

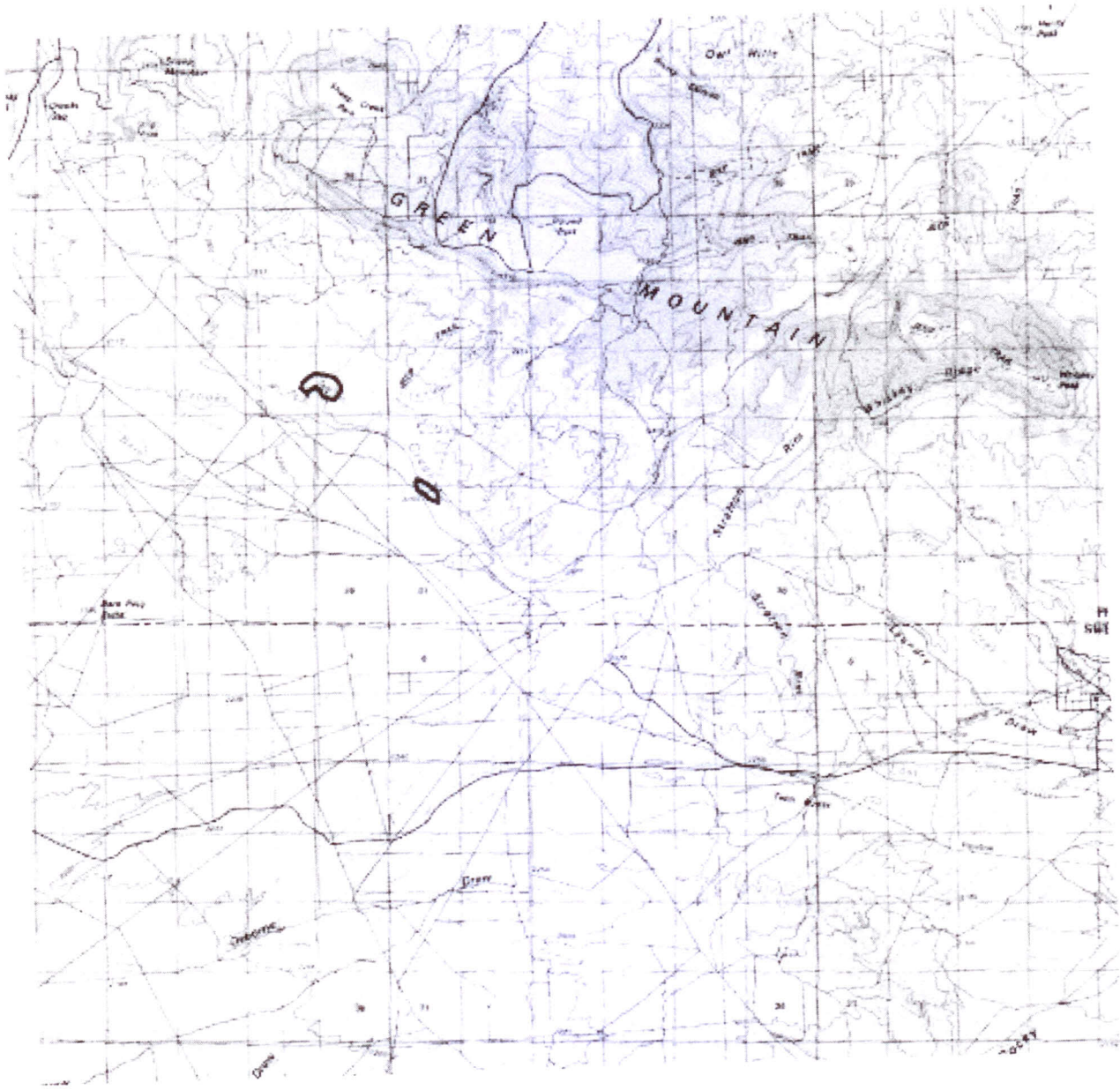
2000 Survey Routes
Baggs BLM 1:100,000 Quads
T17N R90-91W
The Sand Hills

Purple = 2000 survey route



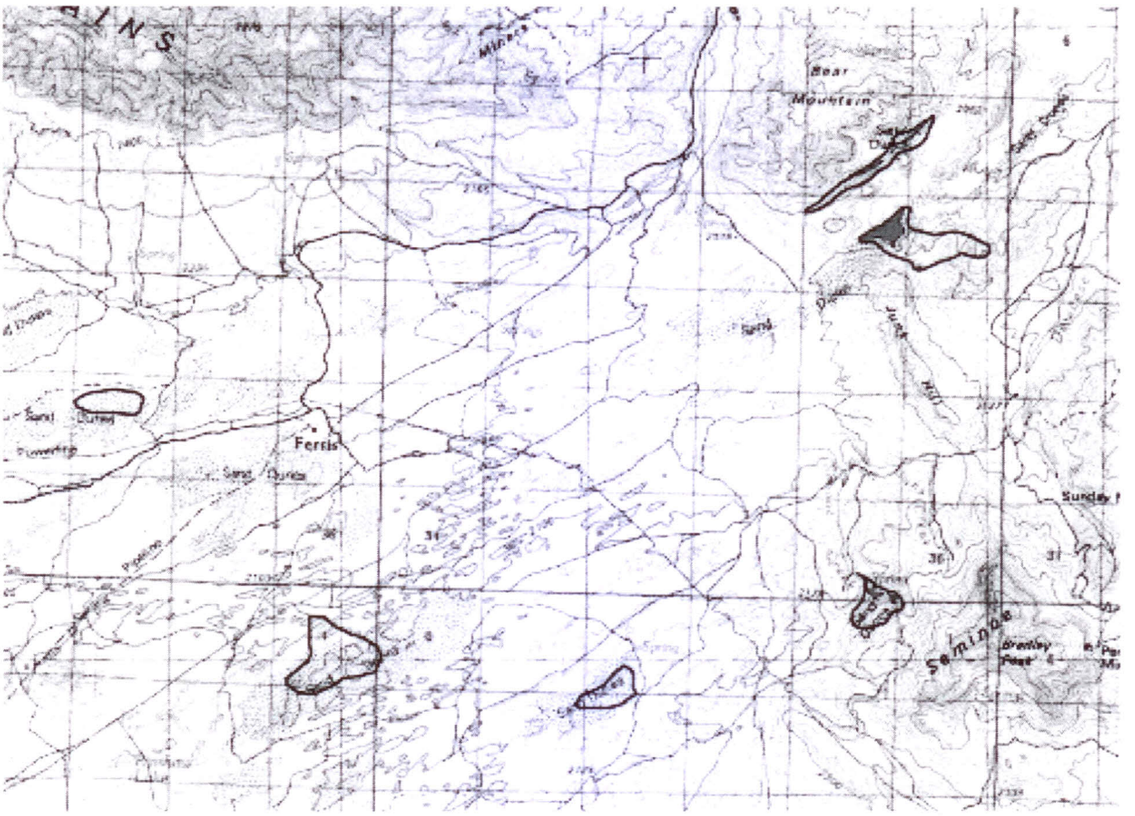
2000 Survey Routes
Bairoil BLM 1:100,000 Quads
T26-28N R91-92W
Green Mountain area

Purple = 2000 survey route



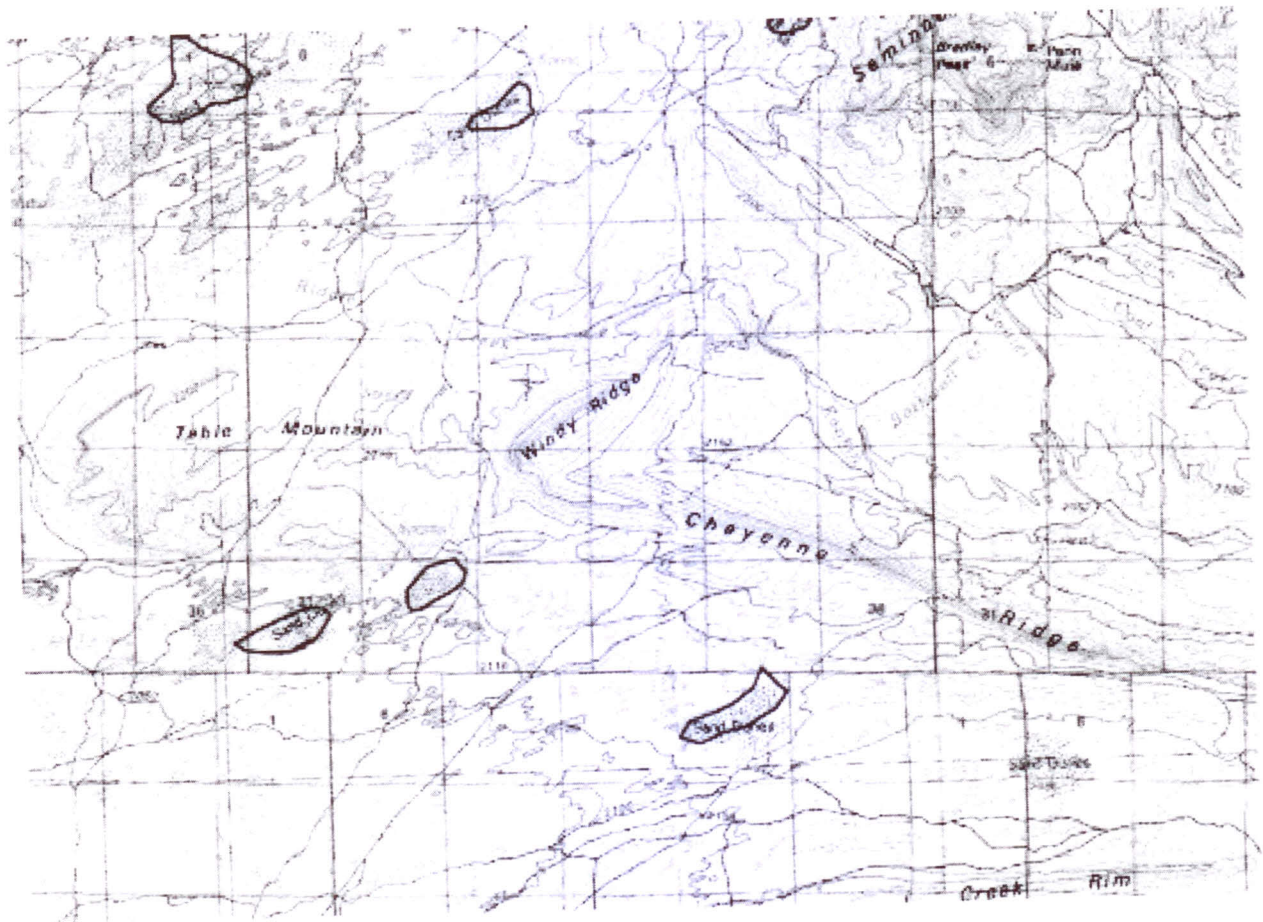
2000 Survey Routes
Bairoil BLM 1:100,000 Quads
T25-27N R86-87W
Ferris Sand Dunes and Bear Mountain/Bradley Peak areas

Purple = 2000 survey route
Blue = Known Blowout penstemon colonies



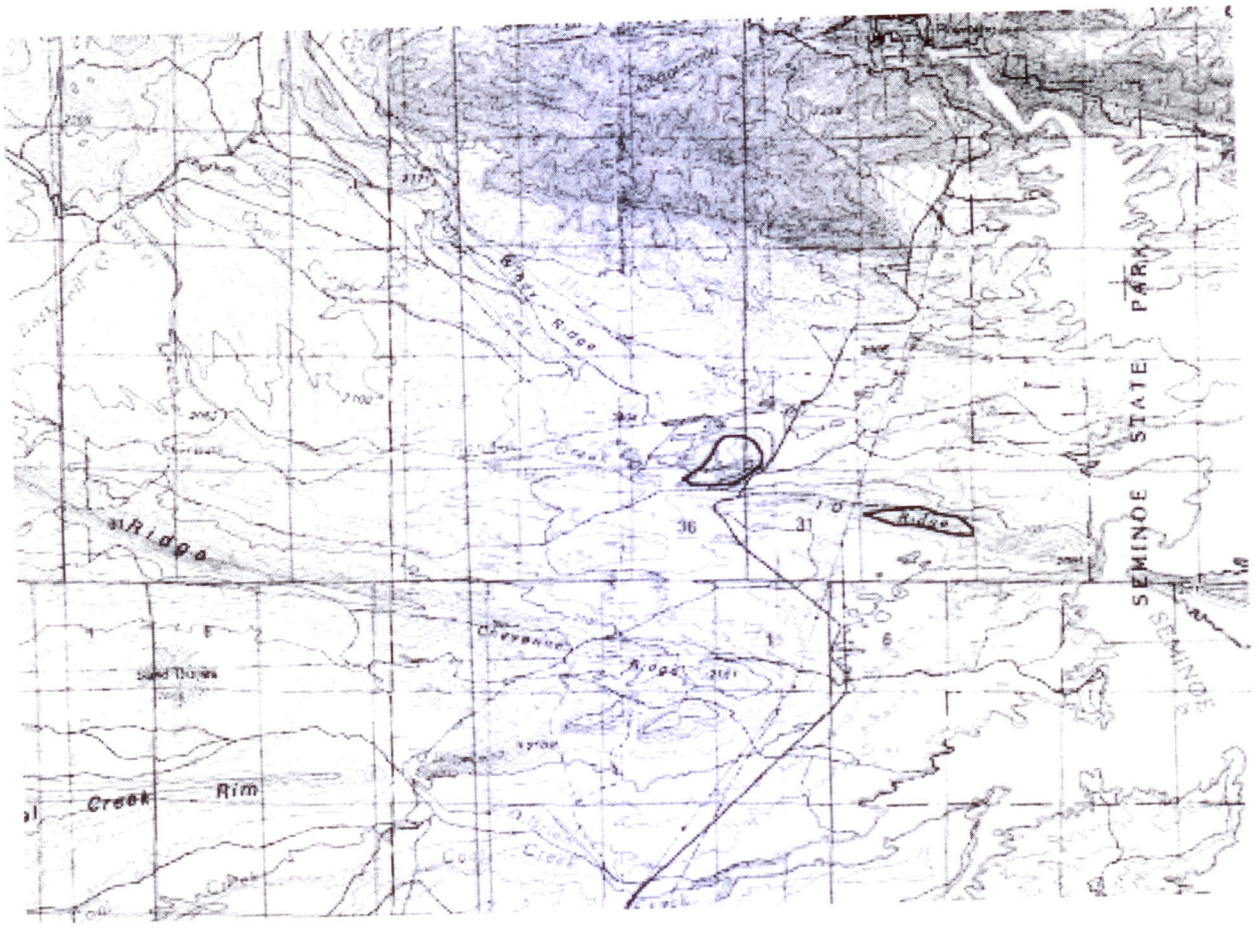
2000 Survey Routes
Bairoil BLM 1:100,000 Quads
T24-25N R85-86W
Table Mountain/Cheyenne Ridge area

Purple = 2000 survey route



2000 Survey Routes
Shirley Basin BLM 1:100,000 Quads
T24-25N R85-86W
ID Ridge/Cheyenne Ridge area

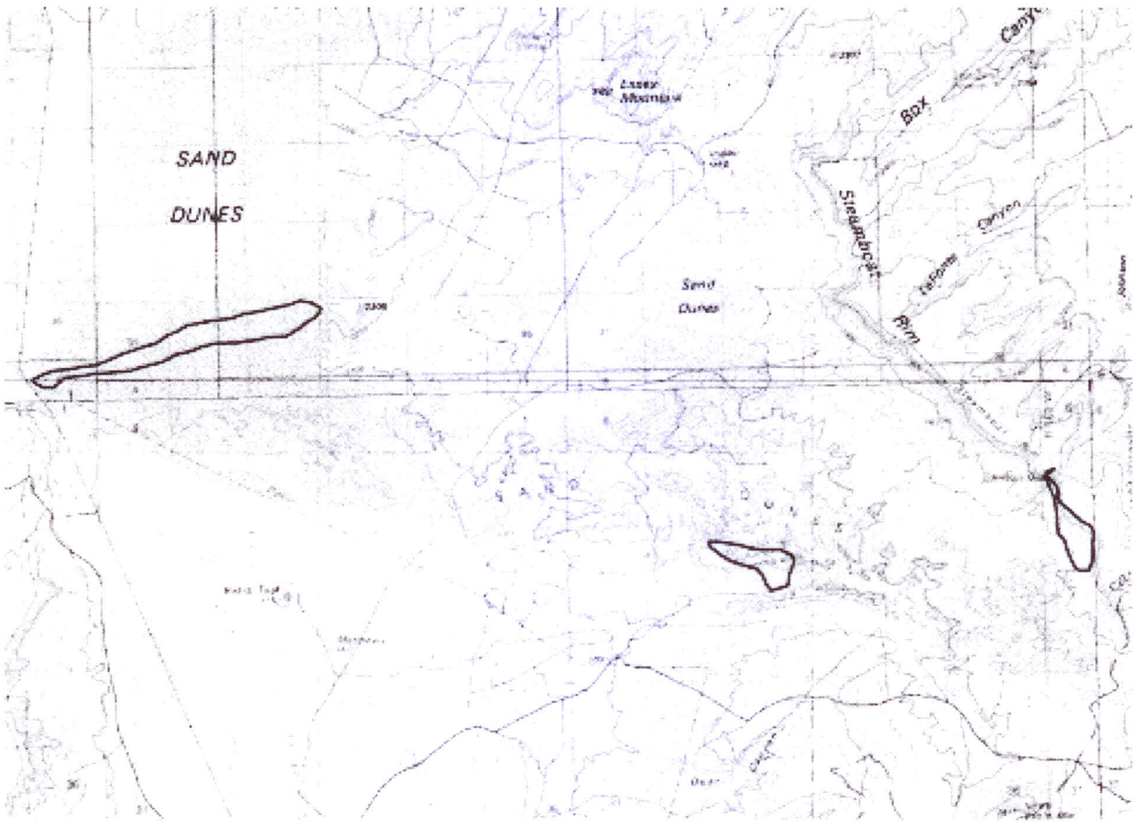
Purple = 2000 survey route



2000 Survey Routes
Rock Springs, Red Desert Basin, Farson, and South Pass BLM 1:100,000 Quads
T23-24N R102-105W
Killpecker Dunes area

(Habitat was also spot-checked along the southern fringes of the Killpecker Dunes in T23N R96-102W, but no suitable sites were observed)

Purple = 2000 survey route



Appendix C

Potential Habitat Model of Blowout Penstemon

Predictive modeling can be a cost-effective means of identifying and prioritizing likely areas of rare plant habitat for more efficient and productive ground surveys. Prior to conducting surveys of Blowout penstemon in the summer of 2000, I developed a simple geostatistical model of the potential distribution of this species using environmental information from the Bradley Peak population. In Arc-view GIS (version 3.1), I queried the statewide coverage of bedrock geology (adapted from Love and Christiansen 1985) to identify areas of Quaternary sand dunes (Figure A). I then intersected the geology layer with the buffered elevation range of the Bradley Peak population (2195-2255 m). The resulting map (Figure B) depicts those areas of the state with high

Figure A. Areas of Quaternary sand dunes (blue) in Wyoming, derived from Love and Christiansen (1985). Red dot indicates the location of the Bradley Peak population of Blowout penstemon (WY EO # 001).

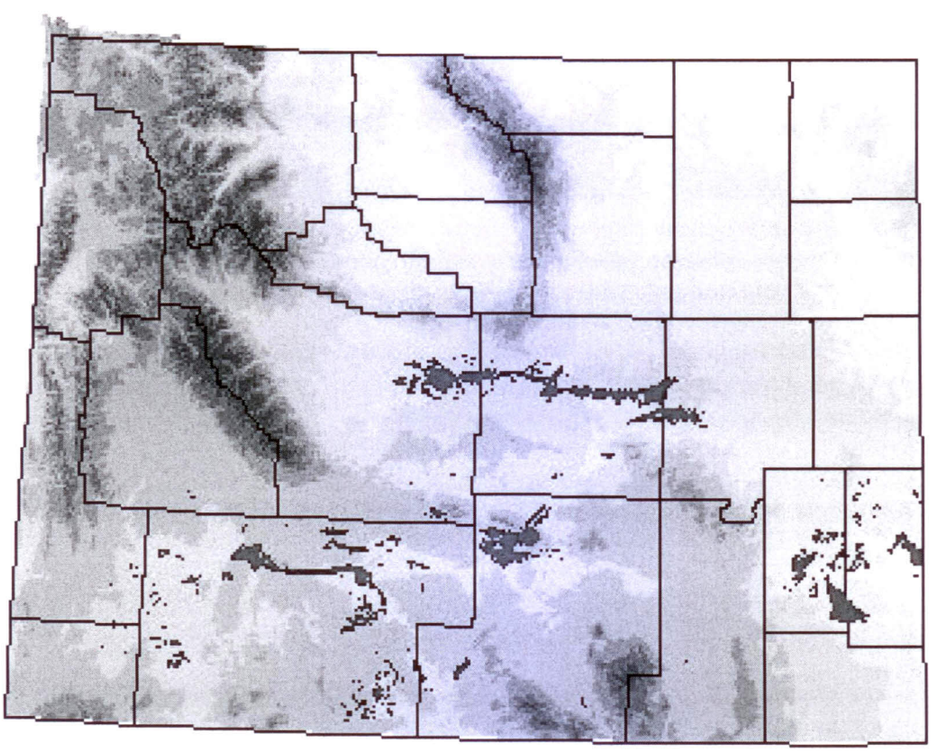


Figure B. Potential habitat of Blowout penstemon in Wyoming based on the intersection of Quaternary sand dunes and elevations of 2195-2255 meters.

elevation sand dunes that might support populations of Blowout penstemon. From this map, I identified specific areas in the Killpecker Sand Dunes of north-central Sweetwater County, the Green Mountains in southeast Fremont County, The Sand Hills in southwestern Carbon County, and the Ferris Mountain/Seminoe Mountain area in northern Carbon County for ground survey in 2000. (The dune area in Albany County was not surveyed and is probably based on a clay dune, rather than an active sand dune.)

By overlapping the model with a digital topographic map, I could identify actual parcels of BLM land for ground survey (Figure C). One of the areas identified on the map was the south slope of Bear Mountain, where Frank Blomquist and I discovered the state's largest population of Blowout

penstemon on 7 July 2000. In some cases, mismatches resulted between the geology coverage and the topographic maps, making areas of potential habitat occur slightly off of their actual location. These errors could be corrected in the field by focusing survey efforts on those sites that visually appeared most suitable.

With additional presence/absence data from more sampling locations, my relatively simplistic model can now be modified and improved. Although a useful tool for the initial screening of potential habitats for rare species, models such as this should not be used as a surrogate for actual, on-the-ground, investigation.

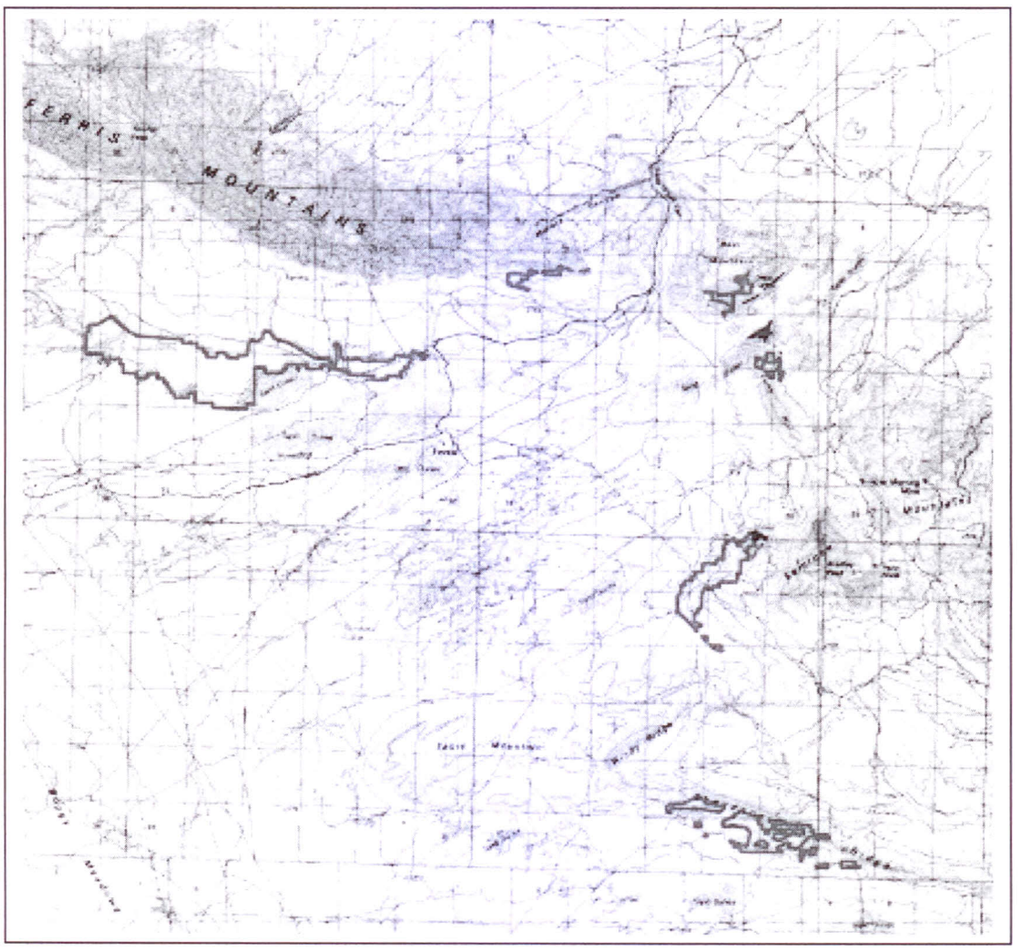



Figure C. Model of the potential habitat of Blowout penstemon (dark green lines) in the Ferris/Seminoe Mountain area overlaid upon a digital topographic map to identify more precise locations for ground survey. Areas in blue indicate known colonies of Blowout penstemon.